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CERTIFICATE OF VERIFICATION

I, Su Hyun LEE of 648-23 Yeoksam-dong, Kangnam-ku, Seoul, Korea state that the attached document is a true and complete translation to the best of my knowledge of the Korean-English language and that the writings contained in the following pages are correct English translation of the specification and claims of the Korean Patent Application No. P1996-10152.

Dated this 29th day of December, 2003

Signature of translator: ________________

Su Hyun LEE

(Translation)

THE KOREAN INDUSTRIAL PROPERTY OFFICE

This is to certify that the following application annexed hereto is a true copy from the records of the Korean Industrial Property Office.

Application Number : Patent Application 10152/1996

Date of Application : April 4, 1996

Applicant : LG Electronics Inc.

Commissioner

(Translation)

[Document Name] Written Application for Patent
[Attention] Commissioner of the Korean Industrial Property Office
[Filing Date] April 4, 1996
[Title of Device] LIQUID CRYSTAL DISPLAY DEVICE
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[ABSTRACT OF THE DISCLOSURE] **96-10152**

[ABSTRACT]

An In-Plane switching (IPS) mode liquid crystal display (LCD) device is disclosed, in which a signal electrode and a common electrode are parallel to substrates, and slanting to a horizontal direction of the substrates. In order to form an irregular electric field applied to a liquid crystal layer, an interval between the signal electrode and the common electrode is less than the thickness of the liquid crystal layer, whereby liquid crystal molecules adjacent to the substrates having the electrodes are rotated according to the electric field, and liquid crystal molecules adjacent to portions having no electrodes are maintained at an initial state. Thus, the liquid crystal molecules of the entire liquid crystal layer are twisted. At this time, retardation value of the liquid crystal layer is satisfied with the following formula: $\lambda/2 < \Delta nd \le \lambda$, wherein, '$\Delta$n' is the liquid crystal refractive anisotropy, 'd' is the thickness of the liquid crystal layer, and'λ' is the wavelength.

[TYPICAL DRAWINGS]

FIG. 5

[SPECIFICATION]

[TITLE OF THE INVENTION]

LIQUID CRYSTAL DISPLAY DEVICE

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG. 1 shows a pixel of a liquid crystal display (LCD) device according to the related art.

FIG. 2 shows a pixel of an LCD device according to the present invention.

FIG. 3 shows an axis direction of an LCD device according to the present invention.

FIG. 4 shows an LCD device according to the present invention.

FIG. 5 shows a pixel of a thin film transistor (TFT) LCD device according to the present invention.

FIG. 6 shows a cross-sectional view taken along line B-B' of FIG. 4.

FIG. 7 shows a driving voltage pulse of a TFT LCD device according to the present invention.

FIG. 8 shows the relationship between amplitude of a data voltage and transmittance in a TFT LCD device according to the present invention.

Description of reference numerals for main parts in the drawings

21: display part	22: metal frame
23: signal line driving circuit	24: data line driving circuit
25: housing	26: second substrate
27: first substrate	31: backlight

32: LCD panel
41: gate line
42: data line
43: common line
48: data electrode
49: common electrode
51: black matrix
55: thin film transistor
59, 62: alignment layer
60: liquid crystal layer
61: color filter layer
63: polarizer
64: analyzer

[DETAILED DESCRIPTION OF THE INVENTION]

[OBJECT OF THE INVENTION]

[FIELD OF THE INVENTION AND DISCUSSION OF THE RELATED ART]

The present invention relates to a liquid crystal display (LCD) device, and more particularly, to an IPS (In-Plane switching) mode LCD device that is capable to obtain a wider viewing angle and a large-sized display.

Recently, a thin film transistor (TFT) LCD device is widely used for a portable television and a notebook computer, and it is required to obtain a large-sized display in the TFT LCD device. The TFT LCD device has disadvantageous characteristics in that it has a viewing angle dependency. That is, the contrast ratio is changed according to the viewing angle, so it is difficult to apply the large-sized display.

In order to solve this problem, various LCD devices are proposed such as a retardation plate attaching TN (Twisted Nematic) LCD device, and a multi-domain LCD device. These LCD devices still have problems of complicated process and shifting color tones.

Recently, an IPS mode LCD device has been introduced to obtain a wide

viewing angle. This technology is discussed in JAPAN DISPLAY 92 P547, Japanese Patent Application No. 7-36058, Japanese Patent Application No. 7-225538, and ASIA DISPLAY 95 P707. As shown in FIG. 1a and FIG. 1b, a liquid crystal layer 12 is formed between first and second substrates 1 and 5, and all of the liquid crystal molecules in the liquid crystal layer 12 are aligned at a predetermined direction to a parallel direction (0°) of the substrates. The polarizing transmittance axis of a polarizer 9 attached to the first substrate 1 is same direction as the alignment direction of the liquid crystal layer 12, and that of analyzer 10 attached to the second substrate 5 is perpendicular to the alignment direction of the liquid crystal layer 12. Referring to FIG. 1c and FIG. 1d, a pair of electrodes 2 and 3 is formed on the first substrate at 90°. When the voltage is applied between the two electrodes, the horizontal electric field is generated. Therefore, the transmittance is controlled in birefringence mode by rotating the liquid crystal molecules. When the rotation angle of the liquid crystal molecules is 45° in the normally black mode, the retardation value (Δnd) is about $\lambda/2$ (0.21-0.36μm) for a maximum transmittance.

However, in order to obtain the retardation value Δnd=0.21-0.36μm in the IPS mode LCD device according to the related art, it is required to form the thickness of the liquid crystal layer at 6μm by using the liquid crystal having low refractive anisotropy about Δn=0.05. Therefore, the driving voltage is increased according to the low dielectric anisotropy due to the liquid crystal having the low refractive anisotropy. Thereby, the driving IC cost is increased and the operation speed is delayed because the high voltage is demanded to drive the low dielectric anisotropy liquid crystal.

In case of using the Twisted Nematic liquid crystal having the great refractive anisotropy of Δn=0.08, the thickness of the liquid crystal layer becomes about 3μm,

whereby the driving voltage is increased. Also, in the related art IPS mode LCD device according to the related art, the transmittance is controlled in the birefringence mode, whereby the color shift is generated at the center portion and left and right directions, and the contrast ratio is decreased. In this respect, it is required to use the retardation plate, whereby the fabrication cost is increased.

[TECHNICAL TASKS TO BE ACHIEVED BY THE INVENTION]

Accordingly, the present invention is directed to an IPS mode LCD device that substantially obviates one or more problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide an IPS mode LCD device to obtain a wide viewing angle and to decrease color shift, thereby improving picture quality.

Another object of the present invention is to provide an IPS mode LCD device to decrease fabrication cost by using a low voltage driving IC used in Twisted Nematic LCD device without a retardation plate.

[PREFERRED EMBODIMENTS OF THE INVENTION]

To achieve these objects and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, a liquid crystal display (LCD) device includes transparent first and second substrates being in parallel to each other; a liquid crystal layer between the first and second substrates; alignment layers coated on the first and second substrates; a polarizer and an analyzer attached on the first and second substrates; a pair of electrodes formed on the first substrate to apply

an electric field being in parallel to the first substrate to the liquid crystal layer;and a driving circuit applying a signal voltage to the electrodes.

At this time, when the voltage is applied, liquid crystal molecules of the liquid crystal layer adjacent to the first substrate have changed optical axes, and liquid crystal molecules of the liquid crystal layer adjacent to the second substrate have no change. When the voltage is applied, the liquid crystal molecules of the liquid crystal layer are twisted, an interval between the electrodes is less than the thickness of the liquid crystal layer, and retardation value (Δnd) of the liquid crystal layer is satisfied with the following formula: $\lambda/2 < \Delta nd \leq \lambda$, wherein, '$\Delta$n' is the liquid crystal refractive anisotropy, 'd' is the thickness of the liquid crystal layer, and'λ' is the wavelength. Also, when the horizontal direction of the LCD device is referred to as 0°, the angle θ_{EF} of electric field applied in the pair of electrodes is satisfied with the following formula: $0° < \theta_{EF} < 90°$, $0° < \theta_{EF} < -90°$.

Hereinafter, a liquid crystal display (LCD) device according to the present invention will be described with reference to the accompanying drawings.

FIG. 2 shows an LCD device according to the present invention. In more detail, FIG. 2a and FIG. 2b show a cross-sectional view and a plan view when the voltage is not applied, and FIG. 2c and FIG. 2d show a cross-sectional view and a plan view when the voltage is applied. Also, FIG. 3 shows an optical axis direction of the LCD device according to the present invention, wherein θ_{EL} is represented as the extension direction of electrodes relative to the horizontal direction (0°), θ_{FE} is the electric field direction applied by the electrodes, θ_{LC1} is the liquid crystal optical axis direction of the first substrate, and θ_{LC2} is the liquid crystal optical axis direction of the second substrate when the voltage is not applied. Furthermore, θ_{PL1} is the polarizing

transmission axis direction of a polarizer, θ_{PL2} is the polarizing transmission axis direction of an analyzer, and $\theta_{LC1'}$ is the liquid crystal optical axis direction of the first substrate when the voltage is applied. At this time, the alignment direction θ_{LC1} of the first substrate is anti-parallel to the alignment direction of θ_{LC2} of the second substrate, and the polarizing transmission axis direction of the analyzer θ_{PL2} is parallel to the alignment direction θ_{LC1} and θ_{LC2}. In addition, the polarizing transmission axis direction of the polarizer θ_{PL1} is perpendicular to the polarizing transmission axis direction of the analyzer θ_{PL2}.

As shown in FIG. 3, the extension direction of electrodes θ_{EL} is slightly slanted compared to the conventional extension direction which is 90° relative to the horizontal line 0° of substrate.

First, as shown in FIG. 2a and FIG. 2b, when the voltage is not applied, entire liquid crystal molecules between the first and second substrates 27 and 26 are aligned parallel to the substrates 26 and 27 by the alignment layers 59 and 62 and to the polarizing transmission axis direction of analyzer θ_{PL2}. At this time, the liquid crystal is Nematic without mixing a chiral dopant.

The light is incident at a direction of the first substrate 27, and the incident light is linearly polarized at the direction of θ_{PL1}, and then is transmitted through the liquid crystal layer 60. Then, the light is incident on the analyzer 64. However, since the polarizing transmission axis direction of the polarizer θ_{PL1} is perpendicular to the polarizing transmission axis direction of the analyzer θ_{PL2}, the light is not transmitted through the analyzer 64, whereby it is shown as the normally black mode.

When the voltage is applied, the parallel electric field 13 of θ_{FE} direction is applied to the liquid crystal layer 60 according to a signal voltage between the data

electrode 48 and the common electrode 49. The parallel electric field 13 is allotted a maximum strength E_1 in the surface of the alignment layer 59 of the first substrate 27, but a liquid crystal threshold strength E_2 in the surface of the alignment layer 62 of the second substrate 26. Also, the middle of the liquid crystal layer 60 has the mean strength ($E_M=(E_1+E_2)/2$). That is, the strength of the electric field is weaker by getting further from the first substrate 27 to the second substrate 26. The irregular electric field in the liquid crystal layer 60 can be obtained by making the thickness of the liquid crystal layer greater than the interval between the two electrodes.

The liquid crystal molecules 77 adjacent to the surface of the alignment layer 59 of the first substrate 27 are rotated according to great effects of the electric field until the optical axis direction θ_{LC1} is parallel to electric field direction θ_{FE}. At this time, the rotation angle θ_{RT1} is $\theta_{BT1}=\theta_{LC1}-\theta_{LC1'}$, and the maximum rotation angle is $\theta_{LC1}-\theta_{LC1'}$.

Meanwhile, the liquid crystal molecules 78 in the surface of the alignment layer 62 of the second substrate is maintained in the state when the voltage is not applied since the electric field applied thereto has the liquid crystal threshold strength, whereby the optical axis direction θ_{LC2} is not changed. Accordingly, the liquid crystal molecules of the liquid crystal layer 60 are twisted to have the optical axes being sequentially changed from θ_{LC1} to θ_{LC2} between the first and second substrates 27 and 26 according to the irregular electric field. At this time, when the light 11 being linearly polarized by the polarizer 63 is transmitted through the liquid crystal layer 60 having the twisted liquid crystal molecules, the polarization direction thereof is rotated according to the twisted liquid crystal molecules in the liquid crystal layer 60, whereby the optical axis direction θ_{LC2} of the analyzer 64 is corresponding to the polarizing

transmission axis direction θ_{PL2} of the analyzer 64. Therefore, the light being linearly polarized by the polarizer 63 and transmitting the liquid crystal layer 60 is transmitted through the analyzer 64, whereby it is shown as the white state.

At this time, the transmittance is a function of the twisted angle ($\theta_{TW}=\theta_{LC2}-\theta_{LC1'}$) of the liquid crystal molecule, wherein, the transmittance increases as the twisted angle (θ_{TW}) becomes large. In other words, grey level of the LCD device is controlled according to the signal voltage for twisting the liquid crystal molecules.

In order to obtain the wide viewing angle at four directions of the LCD device, the polarizer 63 is perpendicular to the analyzer 64, whereby the polarizing axis of any one is provided in parallel or vertical (θ_{PL1}=0°, θ_{PL1}=90°). Also, the alignment direction of the liquid crystal is at 90° on the first substrate, and the alignment direction of the liquid crystal is at –90° on the second substrate, whereby the liquid crystal optical axis directions (θ_{LC1}, θ_{LC2}) are at 90° on the first and second substrates 27 and 26. In this state, in case the extension direction θ_{EL} of the electrodes is θ_{EL}=95°, and the electric field direction is θ_{FE}=5°, the liquid crystal molecule in the surface of the first substrate 27 is rotated from 90°(+θ_{LC1}) to 5°($\theta_{LC1'}$) according to the electric field when the maximum voltage is applied. Also, the liquid crystal molecule in the surface of the second substrate 26 is not rotated, whereby the rotation angle from the first substrate 27 to the second substrate 26 is at 85°.

At this time, in order to maximize the transmittance of the liquid crystal 60 when applying the maximum voltage, the retardation value Δnd of the liquid crystal layer 60 is maintained at Δnd=(85°/90°)=0.94 by controlling the refractive anisotropy (Δn) of liquid crystal and the thickness (d) of the liquid crystal layer 60. Generally, when the Twisted Nematic liquid crystal has the refractive anisotropy (Δn) of 0.06-0.08, and the

light wavelength (λ) is at 0.56㎛, the thickness (d) of the liquid crystal layer is at 6.0~8.8㎛.

Hereinafter, an LCD device according to one preferred embodiment of the present invention will be described with reference to the accompanying drawings.

FIG. 4a shows an LCD device according to one preferred embodiment of the present invention, and FIG. 4b shows a cross-sectional view taken along line A-A' of FIG. 4a. As shown in the drawings, portions of an LCD panel 32 except a display part 21 are covered with a metal frame 22, and a backlight housing 25 containing a signal line driving circuit 23, a data line driving circuit 24 and a backlight 31 is provided in the inside of the metal frame 22. In the display part, a light-guiding plate 75 having a light-diffusion plate, a polarizer 63, first and second substrate 27 and 26 for forming the LCD panel 32, and an analyzer 64 are formed sequentially. At this time, it is possible to form the retardation plate between the polarizer and the first substrate, or between the second substrate and the analyzer to improve the contrast ratio.

The aforementioned LCD device is generally formed in a TFT type such that a thin film transistor (TFT) is formed on the first substrate 27, and a color filter is formed on the second substrate 26. However, a diode type using a diode instead of the TFT, or a simple matrix type using a simple matrix substrate is applicable on the present invention. Also, in the present invention, it is possible to form the TFT on the second substrate, and the color filter on the first substrate, or to form a monochrome type having no color filter layer.

FIG. 5 shows a plan view showing a pixel of a display part in an LCD device, and FIG. 6 shows a cross-sectional view taken along line B-B' of FIG. 5.

In the drawings, an LCD panel includes a TFT 55, a color filter layer 61,

alignment layers 59 and 62 formed on respective surfaces of first and second substrates, spacers formed between the substrates so as to maintain a predetermined interval therebetween, and a liquid crystal layer 60. At this time, polarizers are formed on both surfaces of the LCD panel.

On the first substrate 27, the TFT 55 is formed at a crossing point of a gate line 41 and a data line 42, the gate line 41 extending horizontally (0°) and the data line 42 extending vertically (90°). A common line 43 passes the center of the pixel in the parallel direction with the gate line 41. A common electrode 49 is connected with the common line 43 in the inside of the pixel, and a data electrode 48 is connected with a drain electrode 47 of the TFT in the inside of the pixel in parallel with the common electrode 49.

Herein, the gate line 41, the common line 43 and the common electrode 49 are formed by photoetching a AlTa thin layer (Ta content: 3%) of 0.3㎛ deposited in a sputtering method. In order to prevent short at a thickness direction, and improve insulating efficiency in the surface of the electrode, a AlTa oxidation layer 52 is formed at 0.1㎛ by anodising the surface of AlTa thin layer. Then, a gate insulating layer 57 of 0.3㎛ thick SiNx and an amorphous silicon (a-Si) layer 44 of 0.2㎛ are patterned each deposited layer by plasma chemical vapor deposition method, thereby forming the TFT 55 by photoetching. After that, a Cr thin layer of 0.1㎛ thick is deposited by sputtering, and then is photoetched so as to pattern a signal line 42, source and drain electrodes 46 and 47 of the TFT 55, and a data electrode 48. Then, a n^+ silicon layer of a TFT channel is removed in a drying-etching method by using the source electrode 46 and the drain electrode 47 as mask, whereby a-Si thin layer remains on the TFT channel. In this state, a passivation layer 58 of 0.2㎛ thick SiNx is deposited in the plasma CVD

method, thereby completing the TFT 55, the gate line 41 and the data lien 42. Also, a storage capacitor 53 is formed at the crossing point of the common line 43 and the data electrode 48, whereby it supports to maintain an electric charge of voltage on each pixel.

On the second substrate 26, there is a black matrix 51 and a color filter layer 61. At this time, it is possible to deposit an overcoat layer on the black matrix 51 and the color filter layer 61 so as to provide stability and flatness of the surface. The black matrix 51 is formed of a thin layer of less than 10μm width, for example, 0.1μm thick Cr/CrOx on the near area of the gate line 41, the data line 42, and the common line 43 so as to prevent leakage of light therefrom. The color filter 61 is repeatedly formed with R, G and B layers in each pixel.

In the aforementioned structure, the width of the data electrode 48 is 5μm, the width of the common electrode 49 is 5μm, the interval between the electrodes is 5μm, and the extension direction of the electrodes θ_{EL} is 95° relative to the horizontal direction 0°, whereby the electric filed direction θ_{FE} is 5°.

The alignment layers 59 and 62 formed between the first and second substrates 27 and 26 are obtained by coating the RN1024 (produced in Kousan CHEMICAL CO.) at the thickness of 0.08μm. At this time, the alignment layer 59 coated on the first substrate 27 is rubbed in –90° direction, and the alignment layer 62 coated on the second substrate 26 is rubbed in 90° direction. Also, the spacer 65 is used of Micropal (produced in SEKISUI FINE CHEMICAL CO.) at 8.0μm diameter, to maintain the liquid crystal layer 60 at the mean thickness of 7.8μm, and the liquid crystal is used of ZES5025 (Δn=0.067, $\Delta\varepsilon$=5.0; produced in CHISSO CO.). At this time, the pretilt angle of the liquid crystal is 4.8°, and the retardation value Δnd is 0.41. The polarizing transmittance axis direction of the polarizer 63 attached on the first

substrate 27 is horizontal direction (θ_{PL1}=0°), and the polarizing transmittance axis direction of the analyzer 64 attached on the second substrate is vertical direction (θ_{PL2}=90°).

The interval between the data electrode 48 and the common electrode 49 is less than the thickness of the liquid crystal layer 60. The retardation value (Δnd) of the liquid crystal layer is satisfied with the following formula:

$\lambda/2 < \Delta nd \leq \lambda$,

wherein, 'Δn' is the liquid crystal refractive anisotropy, 'd' is the thickness of the liquid crystal layer, and 'λ' is the wavelength.

Also, the direction of the electric field applied to the data electrode 48 is satisfied with the following formula: $0° < \theta_{FE} < 90°$.

The electroptical characteristics of the aforementioned TFT LCD device will be described with reference to FIG. 6 and FIG. 7.

FIG. 7 shows the driving voltage pulse of the LCD device fabricated according to the present invention, wherein, the LCD device has 12.1inch screen, 480X640(XR·G·B) pixel numbers. Also, the gate voltage (V_0, 71) is V_{GH}=20V, the pulse width of 31μs, V_{GL}=0V (ground), and the common voltage (V_{CO}, 72) is 8V direct voltage. Also, the data voltage (V_0, 73) is monowave signal of 31μs, of which the maximum voltage is +6V, the minimum voltage is +1V, and 5V is controlled in the signal area. Also, the common voltage 72 is controlled to apply only alternating voltage components between the common electrode 49 and the data electrode 48.

FIG. 8 shows a graph showing the relationship between amplitude of data voltage V_U and transmittance of the LCD panel. In the adjacency of the amplitude of data voltage of 5V, the transmittance is the maximum value of 3.6%. That is, in FIG. 8,

the dotted line shows the transmittance characteristics of the LCD device according to the related art having the interval of the electrodes at 10μm, the thickness of the liquid crystal layer at 6.5μm (thickness of the liquid crystal layer between the electrodes). In the dotted line regarding the LCD device according to the related art, the transmittance is increased in case the amplitude of data voltage is 6V. At the portion of 5V in the graph, the transmittance in the LCD device according to the related art is corresponding to 1/4 or less as compared to the transmittance in the LCD device according to the present invention. Accordingly, the LCD device according to the present invention has the great transmittance characteristics even in case of a low voltage.

In case the rotation angle of the liquid crystal molecule in the liquid crystal layer 80 is measured with an LCD panel test device (NIHON DENSHI CO.), the optical axis direction of the liquid crystal molecule formed at the inside portion of 1μm from the surface in the alignment layer of the second substrate 26 is at 88° in state the signal voltage of 5V is applied to the LCD device. Thus, it is known that the alignment direction of the liquid crystal molecule is not rotated adjacent to the surface of the alignment layer of the second substrate 26. Also, the optical axis direction of the liquid crystal molecule formed at the inside portion of 1μm from the surface in the alignment layer of the TFT substrate 55 is at 19°, which is very similar to the estimated rotation angle 15°. Accordingly, it is known that the liquid crystal molecules of the entire liquid crystal layer 60 are twisted at a desired angle.

.In case the data voltage is applied between 1.8V and 5.0V, the viewing angle having the contrast ratio of 5 to 1 or more is in upper and lower directions of ±70° and left and right directions of ± 70°, and this area has no grey inversion. Accordingly, the viewing angle is wider in four directions as compared to the related art

LCD device. In this respect, it is possible to use a general 5V driving IC. Also, the frontal contrast ratio of 120 to 1 is obtained.

In the LCD device according to the present invention, the extension direction of the electric field is at 95°. However, it is possible to select the extension direction of the electric field according to the desired viewing angle characteristics. Also, it is not required to form the alignment layers of the first and second substrates with the same material. For example, the alignment layer coated on the first substrate may be formed of the material having low anchoring energy with the low rubbing density to rotate the liquid crystal molecules since the driving voltage of the first substrate is low. Meanwhile, the alignment layer of the second substrate is formed of polyamic acid for obtaining the small pretilt angle and preventing the residual image to obtain the wide viewing angle, in which the polyamic acid adsorbs foreign matters from the liquid crystal.

[ADVANTAGES OF THE INVENTION]

As mentioned above, the LCD device according to the present invention has the following advantages.

In the IPS mode LCD device according to the present invention, the signal electrode and the common electrode are slanting to the horizontal direction of the substrate, whereby the viewing angle is improved. In addition, the rotation angle of the twisted liquid crystal molecules becomes greater, whereby the thickness of the liquid crystal layer is increased. Also, the low driving voltage is used to maintain the maximum transmittance, so that it is possible to use the cheap driving IC. Furthermore, the linearly polarized light is transmitted through the liquid crystal layer, so that it is not

required to use the retardation plate for compensating the color, thereby decreasing fabrication cost and improving reliability.

What is claimed is:

1.A liquid crystal display (LCD) device comprising:

first and second substrates being in parallel to each other;

a liquid crystal layer between the first and second substrates;

alignment layers coated on the first and second substrates;

at least one pair of electrodes formed on the first substrate for being in parallel to each other, the electrodes formed at an interval less than the thickness of the liquid crystal layer; and

a polarizer and an analyzer attached on the first and second substrates.

2. The LCD device as claimed in claim 1, wherein an alignment direction of the liquid crystal layer is parallel or vertical to the substrates.

3. The LCD device as claimed in claim 1, wherein alignment directions of the alignment layers coated on the respective first and second substrates are perpendicular to each other.

4. The LCD device as claimed in claim 1, wherein a polarizing direction of the polarizer is perpendicular to a polarizing direction of the analyzer.

5. The LCD device as claimed in claim 1, wherein polarizing directions of the polarizer and analyzer are parallel to an alignment direction of the alignment layer.

6. The LCD device as claimed in claim 1, wherein one pair of electrodes are formed at an angle of θ_{EL} relative to a horizontal direction of the substrate.

7. The LCD device as claimed in claim 6, wherein $0° < \theta_{EL} < 90°$.

8. The LCD device as claimed in claim 7, wherein θ_{EL} is at 85°.

9. The LCD device as claimed in claim 6, wherein $90° < \theta_{EL} < 180°$.

10. The LCD device as claimed in claim 9, wherein θ_{EL} is at 95°.

11. The LCD device as claimed in claim 1, wherein retardation value (Δnd) of the liquid crystal layer is $\lambda/2 \Delta nd \leq \lambda$ (Δn: refractive anisotropy of liquid crystal, d: thickness of the liquid crystal layer, λ : wavelength).

12. The LCD device as claimed in claim 1, wherein retardation value of the liquid crystal layer is 0.94λ.

13. The LCD device as claimed in claim 1, wherein the alignment layer coated on the first substrate is formed of the material having lower anchoring energy than that of the alignment layer coated on the second substrate.

14. The LCD device as claimed in claim 1, wherein the alignment layer coated on the first substrate is formed of an inorganic material.

FIG. 1a

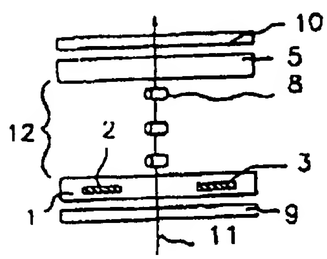


FIG. 1b

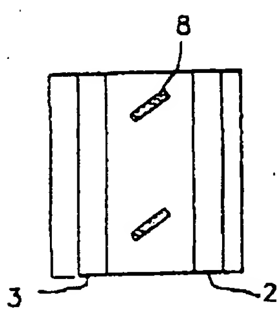


FIG. 1c

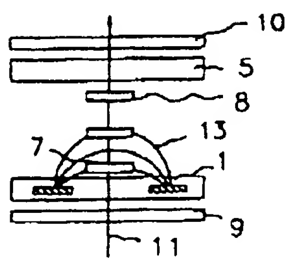


FIG. 1d

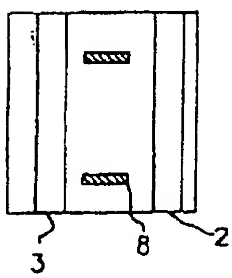


FIG. 2a

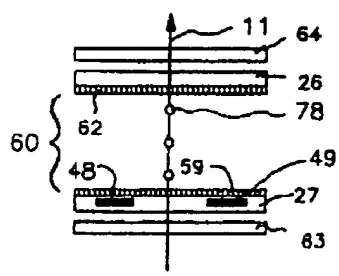


FIG. 2b

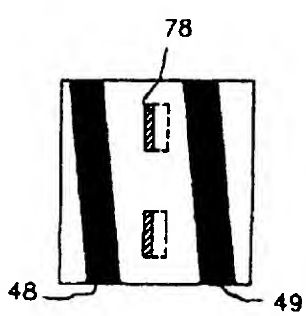


FIG. 2c

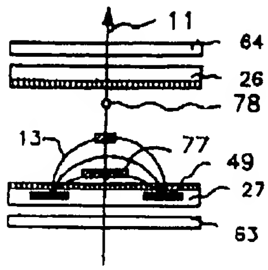


FIG. 2d

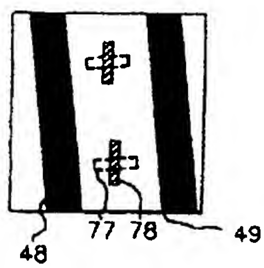


FIG. 3

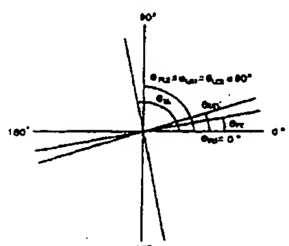


FIG. 4a

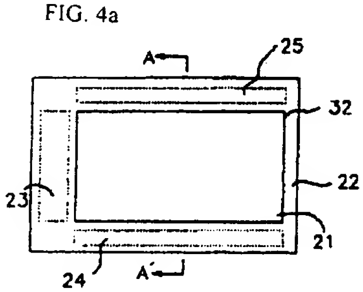


FIG. 4b

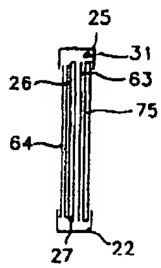


FIG. 5

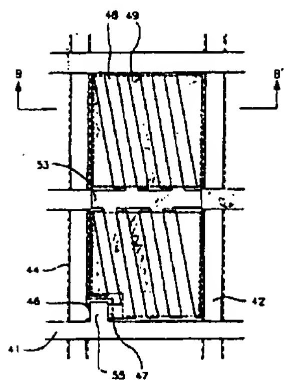


FIG. 6

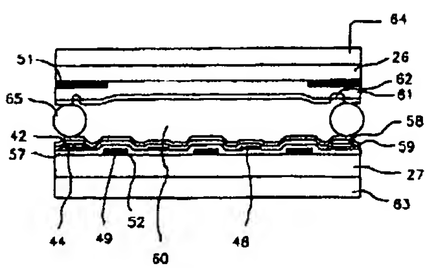


FIG. 7

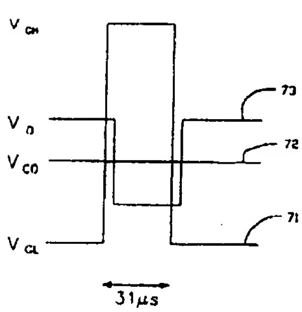
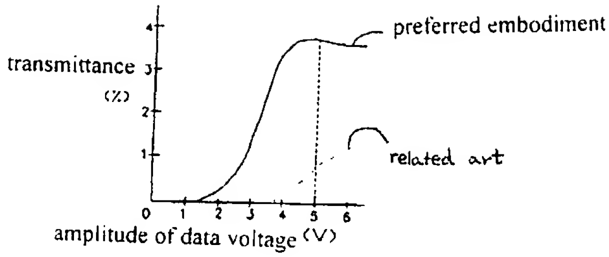


FIG. 8


preferred embodiment
transmittance
(%)
4
3
2
1
0
1
2
3
4
5
6
related art
amplitude of data voltage (V)